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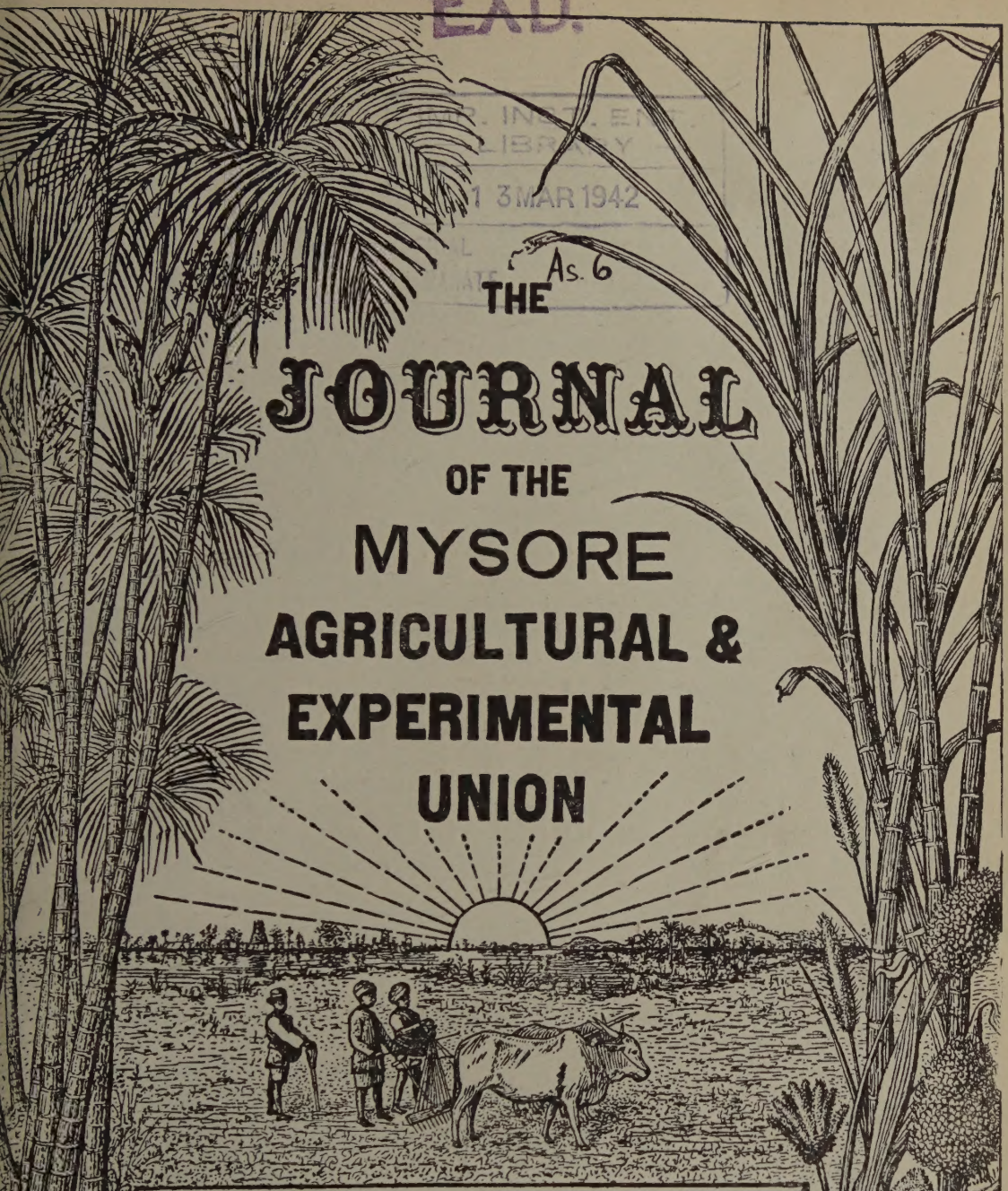

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By Dr. L. S. Dorasami, M.Sc. (Lond.), Ph.D. (Lond.)

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By R. L. Narasimha Swamy, M.Sc.

THE JOURNAL OF THE MYSORE AGRICULTURAL AND EXPERIMENTAL UNION

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The Journal
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The Cultivation of Pulses in Mysore State

By

Dr. L. S. Dorasami, M.Sc. (Lond.), Ph.D. (Lond.)
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Pulses which are important food crops for men and live-stock are grown throughout the State. These occupy a prominent place in rotation and in mixed croppings of the Province. The raiyats realise that in the absence of adequate supply of manure to the dry lands, the use of pulses either in rotation or as mixed cropping is the most salutory method for maintaining the fertility of the soil. It is well known that leguminous plants fix the nitrogen from the air into the soil and thus enrich it. The root nodules of leguminous plants or pulses excrete nitrogenous compounds mostly as amino-acids into the soil. The quantity excreted by these plants is usually more than what they themselves require. The excess of amino-acids thus found in the soil is readily available and advantageously made use of by the cereals or other crops grown along with the pulses. The growing of pulses along with cereals is not only helpful to a better growth of the cereals but it contributes to the raiyat some proteinaceous food material in addition to the cereals

and also a subsidiary income. Further the mixed fodder obtained from combined cropping of cereals and pulses is more nutritive and palatable to the live-stock.

Pulses are consumed in a variety of forms. The most common preparation is in the form of *dhal* for which bengal-gram, black-gram and green-gram are used. Bengal-gram and peas are parched and eaten. Pulses like *Dolichos lab.-lab.* peas, and garden *cajanus* are consumed as vegetables when they are green. Most of these pulses are ground into flour and used in preparation of savouries and sweet-meats. On many festive occasions, soaked and sprouted pulses are eaten. *Bhusa,* the remains found after the threshing of the pulses, is an important article of diet for the live-stock. Horse-gram is given to animals either boiled or soaked and mashed. Crushed seeds of pulses are also given to cattle. It is inferred that the pulses stimulate the flow of milk in milch cows. Pulses are important sources of vitamins. It is found that sprouted pulses of *Kadale* (bengal-gram), *Hesaru* (green-gram) and *Uddu* (black-gram) are excellent sources of vitamin A, B, C and D. In Java pulses like green-gram are consumed regularly for their vitamin B contents as they cure beriberi. Many of the pulses are considered to be good substitutes for meat. According to Dr. Ackroyd, a balanced diet of an adult should contain at least 3 ounces of pulses in combination with other foods per day. The pulses that are commonly used by us are cooked quickly until they are soft, with the result that "about 40 per cent. of the protein content is lost by non-absorption", and they thus lose much of their protein value. It is learnt that pulses "cooked over a slow fire are much more nutritious than cooked hastily over a strong fire".

The most important pulses grown in the State are horse-gram (*Hurali—Dolichos biflorus*), *Togari* (*Cajanus indicus*), *Avare* (*Dolichos lab.-lab.*), bengal-gram (*Kadalai —Cicer arietinuum*), black-gram (*Uddu—Phaseolus mungo*) and green-gram (*Hesaru—Phaseolus aureus*). The area under cultivation approximates to 11,40,000 acres. Of

these 7,89,000 acres are occupied by horse-gram, 1,27,000 acres by *Avare* and 1,20,000 by *Togari*. Bengal-gram is grown in an area of 38,000 acres. The rest of the acreage, 59,000 is made up by black and green-grams. The area under pulses is the largest in Mysore District, comprising nearly 3,70,000 acres. Next in importance is the Chitaldrug District with an acreage of 2,00,000. Hassan and Bangalore Districts have only 1,00,000 acres each. Shimoga, Kadur and Kolar are responsible for nearly 1,45,000 acres. The yield of these pulses is on the average 200–400 lbs. per acre, except in the case of *Togari* which goes up to 1,000 lbs. per acre. The yield of pulses is not adequate enough to meet the demands. There is a deficit in the production of pulses varying from eighteen lakhs of rupees to sixty-five lakhs of rupees per year. Our imports of pulses are greater than the exports. During the last five years the import of pulses has varied from six lakhs to eleven lakhs of railway maunds or to the value of twenty lakhs to seventy lakhs of rupees. The export of pulses during the same period fluctuated from 42,000 to 86,000 railway maunds or to the value of Rs. 1,81,000 to 4,47,000.

Horse-gram.—This is one of the pulses which occupies the largest area in the State. It is a hardy quick growing pulse. It grows on any soil and is perhaps very suitable to light soil and particularly to tracts of scanty rainfall. It is generally grown as a pure dry crop and follows *Jola*. It intercrops well with *Ragi*, cotton, *Togari* and tobacco. The average yield varies from 150–300 lbs. The pulse and the hay are extensively used for live-stock. The grain is also used for human consumption. The best period for cultivation is from August to October. At other times it has a tendency to become more leafy and then it is fit for green manure or fodder purposes.

A collection of all the local varieties has recently been made and the work on the study of the economic and botanical characters is progressing. Since this is an important pulse crop both for cattle and man, attention is being bestowed towards evolving strains which will yield

not only good strains but also good hay. As this pulse is grown for green manure in Cauvery valley it would be appropriate to evolve strains which yield more green matter.

Avare (*Dolichos lab.-lab.*)—It is a common rain-fed crop grown in the dry lands and is extensively used in the diet of the farmers. It is grown as a mixed crop with *Ragi* and *Jola*. *Avare* is the next important pulse which is grown on a large scale. In the districts of Kolar, Bangalore and Mysore, the pulse is grown on vast areas. *Avare* exhibits variations in size of pod, size, form and colour of seed, and yield. This legume suffers considerably from the infestation of pod borers. The varieties grown in the State vary in their resistance to these borers. Selections are being made of promising strains which are disease resistant, mature early and yield well.

Togari (*Cajanus indicus*).—It is an important pulse used in the diet of human beings. It is grown as a pure dry crop or in some cases grown as a mixed crop. Mysore, Tumkur and Chitaldrug are the important areas for *Togari*. It is a drought resistant crop and grows successfully in dry seasons when other crops have failed. The deep root system penetrates any hard soil to a great depth thus aerating the soil and bringing it to a fine condition for subsequent crops. During its life-history the plant sheds a large amount of leaves which enrich the soil with organic matter. The pods are used as stated above in the diet as it is a very nutritious article of food. The husk of the pods and the leaves are used as a valuable article of food for live-stock. The pulse is chiefly used as *dhal* whereas the tender pods are used as a vegetable. There are many varieties of *Togari* but the two main types are: (1) the perennial type which assumes a tree-like appearance and is allowed to grow more than a year, and (2) the annual variety which is grown as a field crop. Breeding work on *Togari* to evolve good strains is progressing at the Hebbal Farm.

Bengal-gram (*Cicer arietinuum*).—It is grown as a dry crop in the black cotton area. Over 35,000 acres are under cultivation. Nearly half of this area is in the Mysore

District. There are many types in this pulse. It is grown as a cold weather crop and is easily attacked by pod borers. The pulse forms an important article in the diet of Mysoreans. The quantity produced in the State is insufficient to meet the demand. It affords a good chance to intercrop with other cold weather crops like wheat, linseed and barley. A large collection of bengal-grams has recently been made. Strains to suit different localities and having desirable economical characters are being isolated. Intercropping with other cold weather crops including pulses is being tried.

Black-gram (*Phaseolus mungo*) *and Green-gram* (*Phaseolus aureus*).—Both these pulses are used as articles of diet and the husk of the pulses and the leaves are greatly relished by the cattle. These pulses are regarded not only nutritious but easily digestible. The area under these is not very great as one would wish it to be. These pulses are cultivated as pure crops, or in mixture.

The demand for pulses is great and as shown above there is already a deficit of about fifty lakhs of rupees worth of these each year. Even with this heavy import, the quantity of pulses used for men and live-stock is very little. The quantity of pulses used per head per day does not even come up to the modest amount of two ounces. As such, to meet our requirements the area under pulses has to be trebled or quadrupled and the yield increased by 300–400 per cent. Since the pulses are grown as dry crops, the acreage under dry farming including black cotton soils is more than adequate for the expansion of their cultivation. With judicious inter-cropping or raising two compatible crops side by side, the question of increasing the production of pulses can easily be achieved without any detrimental effect on other dry crops. The growing of a cereal with pulses is not new to Mysore agriculturists. The inter-cropping of *Ragi* and *Avare,* and *Ragi* and *Togari* is common. The Department has recently demonstrated the advantage of inter-cropping of pulses with *Jola,* castor, cotton and tobacco. The inter-cropping will not only be

remunerative to the farmer, but it enhances the fertility of the soil. By evolving economic strains of pulses and by systematic inter-cropping it will not be difficult to stop the importation of pulses into Mysore but a surplus may be created as well.

Cardamom in Mysore

By

R. L. Narasimha Swamy, M.Sc.

Geneticist, Coffee Experiment Station, Balehonnur

Coffee, cardamom and pepper are entirely associated with malnad areas. In many of the coffee estates there are a few acres of cardamom and several pepper vines. The latter two often come under the category 'for domestic use'. However, they are also grown frequently as subsidiary crops to coffee and especially this is the case with cardamom. Only a few estates wherein cardamom is the major crop exist in the State. Small holdings (*hitloos*) of a few acres in extent are common.

Cardamom is grown almost entirely in the Kadur and Hassan Districts. About 25,000 acres are under cardamom cultivation. A major portion of this acreage is in the Hassan District. Manjarabad Taluk alone is said to contain nearly 11,000 acres. In the Kadur District, Mudigere is the principal cardamom growing area, and this Taluk is said to contain nearly 8,000 acres under cardamom cultivation.

The variety of cardamom grown extensively in the State is commonly called as Manjarabad cardamom. This variety is supposed to have been imported from Malabar and, on this account, it is also called Malabar cardamom. The true Mysore cardamom is not cultivated to any very great extent in Mysore. However, in many of the estates one can obtain a few plants belonging to several varieties—Malabar, Mysore, Ceylon, etc.,—chiefly grown as curios.

Malabar cardamom is the type of the species *Elettaria cardamomum*, Maton., belonging to the family *Zinziberaceæ*. The plants are perennial herbs. The leaf stalks grow up to 11 ft. in height. The linear-lanceolate leaves may be either smooth or hairy on the under surface. The inflorescences which arise from the rootstock are spreading on the ground. The fruits are globular and characteristic of the variety. They are comparatively smaller than the fruits of Mysore cardamoms.

Mysore cardamoms are robust plants. The leaf stalks grow up to 17 ft. in height. The inflorescences are either

spreading on the ground or grow erect. The fruits are distinctly three-angled.

Ceylon cardamoms appear to resemble closely *E. cardamomum* var. *major,* Thw. The plants are robust like the Mysore cardamoms. The inflorescences grow erect. The fruits are oblong-fusiform.

Another variety which may be named laxiflora is characterised by the lax inflorescences in which the sub-branches and the flowers on them are arranged loosely. The inflorescences spread on the ground. The fruits develop upto 1 inch in length.

All the four varieties are growing side by side on the Government Coffee Experiment Station, Balehonnur, from material collected by Mr. K. H. Srinivasan, M.A., B.Sc. (Edin.), to whom the writer is indebted for the permission given to him to utilise the material for analytical study.

Yield record of selected plants of the varieties of cardamoms in lbs.–ozs. of ripe fruits

Variety	Plant Nos.	Age in years during 1939–40	1934–35	1935–36	1936–37	1937–38	1938–39	1939–40
Malabar ..	1	9	2–0	3–2	2–1	0–1	0–1	0–13
	2	,,	2–11	1–12	0–14	0–7	0–7	0–13
	3	,,	1–4	0–15	1–5	0–0	0–5	2–0
	4	,,	1–5	0–11	0–11	0–10	1–0	2–13
	5	,,	..			2–9	2–4	3–11
	6	,,				0–14	1–13	2–9
Mysore ..	1	,,	0–8	0–4	0–1	2–1	0–2	2–8
	2	,,	0–13	0–3	0–0	0–13	1–4	1–14
	3	,,	0–7	0–2	0–0	0–1	0–8	2–11
	4	,,					1–3	2–4
	5	,,					3–12	1–11
	6	,,				0–13	0–14	1–3
Ceylon	1	9½	0–0	0–9	0–13	1–10	1–1	1–7
	2	,,	1–4	0–1	0–2	0–1	0–0	0–0
	3	,,	0–0	0–2	0–0	0–14	0–14	0–8
	4	,,					2–9	1–8
	5	,,					2–9	1–8
	6	,,					3–5	1–4
Laxiflora ..	1	7				3–0	5–5	0–5
	2	,,				2–3	2–2	2–2
	3	,,				1–13	2–5	1–12
	4	,,				1–7	1–13	1–5
	5	,,					3–12	1–11
	6	,,					2–11	2–15

Average yield per plant of the varieties of cardamom calculated from the plot yield of the varieties in lbs.–ozs. of ripe fruits

Variety	Age in years during 1939–40	1934–35	1935–36	1936–37	1937–38	1938–39	1939–40
Malabar ..	9	0–7	0–7	0–8	0–5	0–10	0–15
Mysore ..	9	0–7	0–4	0–4	0–6	0–13	0–13
Ceylon ..	9½	0–1	0–2	0–2	0–3	0–6	0–4
Laxiflora ..	7					2–4	1–2

Under the conditions obtained at the Station, Ceylon cardamom does not appear to be a good yielding variety. Laxiflora appears to be better than the other varieties in yield. Planters who have grown Ceylon cardamom on a large scale express their opinion that the variety is a low yielder in comparison with Malabar. They class the variety in the same category as the uneconomic hybrid coffee plants which are to be found in many of the estates. Usually the fruits of Ceylon cardamom begin to ripen later than those of the other varieties and, when fully ripe they are yellowish-green whereas the fruits of the other varieties are yellow.

Analyses of fruits of the varieties of cardamom

	Wt. of one hundred ripe fruits in grams		Wt. of one hundred dry fruits in grams		% Wt. of dry to ripe fruits		% Wt. of moisture lost by the husk in drying		% Wt. of moisture lost by the seeds in drying		No. of seeds per hundred fruits		% of oil content in seeds*
	1938-39	1939-40	1938-39	1939-40	1938-39	1939-40	1938-39	1939-40	1938-39	1939-40	1938-39	1939-40	
Malabar ..	75·2	81·4	16·5	17·5	21·9	21·6	90·3	91·0	49·6	50·1	1242	1313	18·98
	± 2·17	± 2·55	± 0·89	± 0·49	± 0·52	± 0·51	± 0·17	± 0·17	± 1·27	± 1·20	± 51	± 38	
Mysore ..	88·7	88·7	18·6	17·3	20·9	19·4	90·2	90·4	54·8	59·8	1341	1228	20·14
	± 2·09	± 2·25	± 0·74	± 0·67	± 0·38	± 0·44	± 0·17	± 0·30	± 2·04	± 1·14	± 36	± 43	
Ceylon ..	69·7	62·7	17·2	13·7	24·8	21·9	86·5	88·0	56·1	61·2	1006	973	20·54
	± 1·96	± 1·90	± 0·65	± 0·37	± 0·86	± 0·41	± 0·93	± 0·23	± 1·85	± 0·77	± 52	± 42	
Laxiflora ..	87·3	86·2	19·6	18·7	22·4	21·6	90·0	90·0	51·1	54·5	1402	1473	19·14
	± 1·04	± 2·75	± 0·64	± 0·84	± 0·39	± 0·40	± 0·25	± 0·39	± 1·22	± 1·47	± 132	± 77	

* Oil contents were kindly determined by Dr. B. T. Narayanan, B.A., Ph.D., to whom my thanks are due.

Ripe fruits of the Ceylon variety weigh less than those of the other varieties; but, there does not appear to be much difference when the fruits are dried, though in 1939–40 the dry fruits of the Ceylon variety weighed less. The fruit-skin of the Ceylon variety loses less moisture content and the seeds more, while drying than those of the other varieties. When the outturn, *i.e.*, per cent. weight of dry to ripe fruits, is considered there does not appear to be any appreciable difference between the varieties though during 1938–39 the outturn of the Ceylon variety appears to be significantly high. However, there appears to be slight annual variations in the outturns of the varieties.

The fruits of the Ceylon variety contain fewer seeds; but they are larger and flatter. This variety also appears to contain more oil than others; and, Malabar cardamom has the lowest oil content. The cardamom merchants in the Manjarabad area like the globular Malabar fruits better. It is said that the seeds of these fruits are superior in flavour. Ceylon cardamom fruits are said to be liked by the Continental countries like Sweden for the ease with which they can be bleached. Big fruits like those of

Analyses of fruits of individual plants to show extremes of variation in the varieties.

Variety	Wt. of one hundred ripe fruits in grams	Wt. of one hundred dry fruits in grams	No. of seeds per one hundred fruits
Malabar :			
1. Minimum ..	63·4	13·8	827
2. Maximum ..	99·0	21·3	1647
Mysore :			
1. Minimum ..	66·9	11·9	946
2. Maximum ..	104·7	24·4	1768
Ceylon :			
1. Minimum ..	55·0	12·9	616
2. Maximum ..	75·0	15·0	1348
Laxiflora :			
1. Minimum ..	72·3	17·5	1285
2. Maximum ..	112·2	24·3	1725

the Mysore variety are said to be liked by particular markets, *viz.,* Hyderabad, to which they are exported. As yet laxiflora is not being grown on a commercial scale.

The last table indicates the extremes of variation observed while analysing the fruits of individual plants. The variation is striking and it suggests the possibility of selection within the varieties and the breeding of good and desirable plants.

Malabar cardamom is highly susceptible to *Katte* disease while Mysore and Ceylon varieties are resistant to it. In the cardamom estates the latter may easily be picked up by their robust and vigorous growth and dark-green colour of the foliage as well as by their resistance to the disease. However, the fruits they produce in the erect inflorescences are more prone to be attacked by thrips than the fruits of the Malabar variety produced in inflorescences spreading on the ground. In the cardamom areas round about Manjarabad, the planters point out that the damage caused by thrips commonly known as *Kaggi Roga* is almost negligible with the fruits of Malabar cardamom.

The breeding work on cardamom that is being carried out at the Station may now be mentioned. The aims of the work are: (1) selection of desirable plants from among the varieties and testing their progeny by self-pollination, *i.e.*, pure line selection and (2) cross-breeding different varieties with a view to combining the desirable characters of the varieties.

The breeding technique is simple. For selfing several methods were tried. The simplest and at the same time the easiest is to enclose the growing inflorescences in a brass wire gauze tube of a very fine mesh. Hand pollination of flowers enclosed in waterproof paper bags was tried with success.

Cardamom plants do not flower all at once. They continue to flower for a long time. A few flowers can be obtained almost throughout the year. The principal flowering season appears to extend from after the first showers in March or April up to August or September. This continued flowering, therefore, extends and at the same time

makes tedious the breeding operation. However, it has been observed that a good percentage of flowers set in light showery weather. At the Station the breeding work can be easily carried out during June.

The flower buds are emasculated the day previous to their opening. Emasculation is done by hand without the help of any instrument. The flower bud is so slit that the anther gets divided longitudinally. Then the anther halves are pulled out and the emasculated bud is bagged. Next morning the bud is pollinated and rebagged. The bag is removed three days after pollination. Pollination is done best in the morning hours.

The flowers last for a day. Stigmatic surface remains receptive for about 48 hours after the flowers open. From germination tests it has been observed that the pollen is highly viable when it is fresh. Pollen taken from flowers two days old shewed poor germination. Actually there remain few grains on the flowers even a few hours old as the Indian honey bee which is the principal pollinating agent eats up the pollen grains and incidentally also pollinates the flowers. Cardamom is essentially a cross-pollinated plant.

Several crossings have been effected using different varieties. The ideal plant in view is one with the robust growth habit and resistance to *Katte* disease of either Mysore or Ceylon varieties and the fruit characters of Malabar variety. The magnitude and complicated nature of the work in obtaining this ideal is self-evident especially, when it is remembered that cardamom is a perennial crop coming to bearing for the first time in its third year. Further, the progeny from the ideal plant must breed true. It is then that the plant will be of any great value. Though the comparatively easy method of propagation by vegetative means *i.e.*, by splitting and planting the bulbs is to hand, the ideal plant can only spread to large areas in a short time by seed. Therefore, it will be observed that cardamom breeding requires patient and hard work to be extended over a series of years Towards this end work is in progress on scientific lines.

Experimental Methods in Coffee

By

A. Ananthapadmanabha Rau, B.A., F.R.Met.Soc.
Statistician, Department of Agriculture, Bangalore

"A field experiment with a heterogeneous crop is a complicated and precarious business calling for the utmost care and patience. .... It is now universally recognised that certain data must be accumulated before precise field experiments can be successfully carried out. The most important data are the individual tree records, uniformity trials, knowledge of plot size and for precise work standardised material."

GILBERT,
Chief Scientific Officer.

Coffee Research Station,
Kenya.

Field experiments with coffee have not been very successful in yielding significant results in India. This is due to the very high experimental errors caused chiefly by one or more of the following factors, namely, heterogeneity of the soil and the plant material, small-sized plots and lack of a sufficient number of replications. It is necessary that the chief causes of error contributed by each of the above sources of error are determined before field experiments are laid out. In all field experiments the random errors must be reduced to the minimum, so that even small differences in the yields between the differently treated plots or varieties may be detected. The author has not come across any investigation made so far on the errors involved in field experiments with coffee in India. Recently, Gilbert at Kenya investigated this problem and has shown the lines on which experiments with coffee at Kenya can successfully be carried out.

Application of statistics to agriculture, particularly the technique of field experimentation made great advances recently. Experimenters recognised that in addition to varietal, cultural or manurial effects on crop yields, factors such as the heterogeneity of the soil and of the plant material and the environment were also responsible in bringing about differences in the yields. Prof. Fisher has devised methods to deal with this problem. "The two arrangements devised by Prof. Fisher are the methods of Randomized blocks and the Latin Square, both belonging to the orthogonal type; in each of these the differently treated plots are so arranged that an accurate estimate of the soil variation is possible. In a Randomized block arrangement, each plot yield may be viewed as in part due to the particular block in which it is situated, as in part due to the particular treatment and as in part due to a residue on account of what is called error. Fisher's analyses of variance separates the total variance into these component parts. In the Latin Square much better is the estimation separately and directly of these items of variance." And more recently, factorial designs and methods devised and perfected by Prof. Fisher and Yates have given a powerful tool in the hands of the investigators.

The planning of the lay-out largely depends on the objects of the experiment, limitations of ground and the difficulties of management. The two important considerations are the size of plot and the number of replications. These depend on the variability of the soil and the plant material and the magnitude of differences in yields expected to be measured between the differently treated plots.

Perennial crops, unlike the annuals, have always given great difficulties to the experimenter. Of the two principal and inevitable sources of error, the plant material and the soil, the former has always predominated in the case of perennials. The errors arising out of these two sources of errors are at times so huge that even big differences obtained by treatments are negligible. Field experiments with perennial crops like tea, pineapples, coconut, etc., have not been unsuccessful because investigation on the fundamental

aspect has been carried out. Most of the investigators have pointed out that the variability contributed by the soil is many a time insignificant compared to that contributed by the plants.

Coffee is a crop peculiar in that there are many factors which tend to induce the development of great individuality among the plants. Differences in shade, age, slope, aspect, mulching, etc., develop much variability in the plant yield. The above factors and the differences in the genetic make-up cause great variability in the yielding capacity of the plants with the result that soil heterogeneity is often found to play a minor part in influencing the experimental errors.

One great difficulty with coffee, is the small number of plants (1,200 to 1,500 plants per acre) available for a plot of moderate dimensions, unlike in other crops. The result is that the error met with would be high due to the fact that the sample available for experiments ordinarily would not be a good representative of the population.

Another complicating factor, which introduces great variability, is the existence of periodicity in the yielding capacity of coffee plants. This varies from three to six years depending on the soil, the plant and the climatic conditions. Differences in the phase of this periodicity among the coffee plants in a plot however homogeneous they may appear to be, contributes much towards the increase in variability.

The variation in coffee yields in any one season in a plot treated uniformly may be attributed to one or more of the factors mentioned previously. The total variability caused thus cannot be estimated and hence is included in the error which must be reduced to the minimum so that differences in yields caused by treatments or varieties tested can be detected and judged on the basis of this error. The trial discussed in the next section was conducted at the Mysore Government Coffee Experiment Station, situated at Balehonnur.

Uniformity Trial on Coffee at the Balehonnur Coffee Experiment Station.—Balehonnur (Lat. 13° 22′; Long.

75° 27′) receives an annual rainfall of 105 inches, the number of rainy days being 128 on an average. The mean maximum and minimum temperatures are 80.2° F. and 63.7° F. respectively for the year. The major portion of the coffee plantation consists of Arabica type of coffee of 30 to 40 years of age and the elevation of the plantation ranges from 2,700 to 2,935 feet above mean sea-level.

The block of coffee selected for conducting this uniformity trial, though the best available on the station with minimum number of supplies and vacancies, was not uniform in the age of the plants and the environment. This area of about two acres, with 26 rows, each with at least 60 plants of 30 to 40 years of age, has been planted on an average 6 feet apart. These are being sprayed with 0.5 per cent. strength Bordeaux mixture twice every year before and after the south-west monsoon, for the past seven years. All other operations of the estate, like pruning, weeding, digging, etc., are being done for this area. On the eastern and the western sides, there are small roads and on the northern and southern sides there are unsprayed control plots of very much smaller dimensions. The block is fairly level, with a slight elevation at the middle, the ridge running north and south.

For purposes of this trial, only 60 plants in each row were selected. Three pickings were given at intervals of about fifteen days. The first picking was on the 17th November, the second on the 10th December 1936 and the final stripping of all berries present on the 1st January 1937. The totals of the three pickings are given in Table I in lbs. of fruits for each of the 1,560 plants in the block.

Only 24 rows of 60 plants each have been considered for calculating the relation between the plot-size and the experimental errors. This area of 1,440 plants was divided into 144 plots, each plot containing 2 rows of 5 plants or 10 plants. The division was such that plots could be arranged in a 12 × 12 Latin Square. The total yields of the three pickings in lbs. of fruits for each of the 144 plots are given in Table II. Variation of yields exhibited by the individual plots is calculated and from this the variation caused

by rows and columns and imaginary treatments imposed are removed to obtain the variation due to experimental errors for this particular plot-size. Then bigger plots are built from these individual plots by uniting two contiguous plots and the experimental error is determined. This process is repeated for bigger and bigger plot-sizes and their experimental errors determined in order to build up the relation between plot-size and experimental errors. In this, only four plot sizes namely 10, 40, 90 and 160 plant-plot-sizes are considered.

In order to arrive at conclusions comparable with those obtained when an actual experiment is conducted, a design embodying all the typical features of an experiment, is considered in each case. Hypothetical treatments are imposed on the plots of the uniformity trial. The yield figures with the treatments are given in Tables II, III, IV and V. The variance contributed by the treatments is compared with that of the experimental error by the usual Z-test of significance. If they are not significantly different, a new variance is obtained from the combined sum of squares for error and treatments, as suggested by Eden. The two variances for treatment and error are "really independent estimates of random variances and should be statistically equivalent". The new variance is determined in each case and the standard error is expressed as percentage of the mean yield. The relation between the plot-size and the error is found by plotting the two and finally the optimum size of the plot with minimum error is determined. The statistical analyses is given below.

The yield figures in lbs. of fruits are given in Table II with the statistical analyses.

TABLE I

12 × 12 *Latin Square*

The yield figures in lbs. of fruits are given in Table II with the statistical analysis

24·72	30·22	39·73	36·87	33·44	21·23	27·89	26·00	38·17	29·17	26·48	30·33
34·51	38·12	37·03	37·18	27·43	22·03	24·66	25·40	32·88	26·43	31·00	25·10
27·80	38·62	26·44	33·08	36·21	33·28	27·73	28·35	31·14	29·68	35·04	25·87
7·10	30·18	31·56	28·38	27·28	31·09	27·44	28·13	36·98	30·98	30·24	27·56
6·64	9·10	25·54	33·36	36·04	21·33	27·01	27·92	32·00	19·64	20·05	33·94
43·72	16·35	28·13	33·21	40·01	29·18	19·13	16·14	32·08	21·20	30·30	21·08
36·38	15·68	26·13	42·15	36·68	29·11	23·35	23·50	36·98	18·39	24·17	27·21
41·09	26·40	30·80	40·40	24·53	30·36	28·94	25·27	29·63	32·09	20·33	16·90
29·22	38·93	29·35	30·39	22·80	34·80	30·58	26·96	20·60	12·08	23·39	13·66
31·46	32·29	13·17	14·43	19·45	28·13	19·58	21·73	21·19	17·62	21·04	31·94
37·08	17·58	12·89	21·46	35·05	31·59	20·20	26·10	15·67	13·26	26·59	33·14
42·08	16·08	27·67	21·89	25·95	30·43	22·11	18·66	14·34	25·96	23·43	32·30

The totals for the rows, columns and treatments are given separately. Under ideal conditions of uniformity of soil, plants, etc., the totals of each of the rows, columns and treatments should have been equal. The fact that it is not so illustrates how experimental results are affected by other disturbing factors.

Analyses of variance for 12 × 12 *Latin Square*

Mean yield per plot of 10 plants = 27·24 lbs.

Variance due to	Degrees of Freedom	Sum of Squares	Mean Square
Rows	11	981·6025	89·2366
Columns ..	11	853·5801	77·5982
Treatments ..	11	384·4681	34·9517
Error	110	5631·8941	51·1990
Total	143	7851·5434	54·9059
Error+Treatments	121	6016·3622	49·7220

Standard error per plot .. 7·01 lbs. or 25·8% of the mean yield

Tests of Significance

	Z calculated	Z significant for P = 0·05
Rows *v.* Error (new)	0·2924	0·3071
Columns *v.* Error (new) ..	0·2225	0·3071
Totals *v.* Error (new)	0·0496	0·1452
Treatment *v.* Error	−0·1910	0·4387

The variances contributed by each are compared by the Z-test which is half the difference of $\log_e$ of the mean squares. These are tested for significance with the 5 per cent. values of Z published by Prof. Fisher. It is seen that the variance contributed by treatments is not significant compared with the error, which means that the randomisation of the Latin Square is satisfactory. Hence, a new error

obtained by a combination of the two sources of random variances is taken to judge other variances. Row and column variances are not significant indicating the absence of much heterogeneity in the soil. The standard error per plot is 7.01 lbs. or nearly 26 per cent. of the general mean. Next a bigger sized plot is considered by amalgamating four plots of the 12 × 12 square to form a 6 × 6 Latin Square and the same analyses is done. The yield figures are given in Table II in lbs. of fruits for each of the plots.

TABLE II

6 × 6 *Latin Square*

127·57	150·81	104·13	103·95	126·65	112·91
103·70	119·46	127·86	111·65	128·78	118·71
75·81	120·24	127·06	90·20	104·92	105·37
119·55	139·48	120·68	102·06	117·09	88·61
131·90	87·34	105·18	98·85	71·49	90·03
112·82	83·91	123·02	87·07	69·23	115·46

Analyses of variance for 6 × 6 *Latin Square*

Mean yield per plot of 40 plants = 108·96 lbs.

Variance due to	Degrees of Freedom	Sum of Squares	Mean Square
Rows	5	3163·5418	632·7084
Columns	5	1832·9995	366·5999
Treatments ..	5	732·7096	146·5419
Error	20	7235·1494	361·7575
Total	35	12964·4003	370·4127
Error + Treatments or Error (new)	25	7967·8590	318·7143

Standard Error per plot: 17·83 lbs. or 16·4% of the mean.

Tests of Significance

	Z calculated	Z significant for P = 0·05
Rows *v.* Error (new)	0·3434	0·4783
Columns *v.* Error (new) ..	0·0700	0·4783
Totals *v.* Error (new)	0·0752	0·3180
Treatments *v.* Error	—0·4520	0·7584

It is noticed that as before the treatment variance is not significant which justifies the combination of the variances contributed by treatment and the error to form a new variance called Error (new). On the basis of this new error, neither the row nor the column variances are significant. The standard error per plot is 17.83 lbs. or 16.4 per cent. of the mean. Thus with 40 plant plots, arranged in a 6 × 6 Latin Square, the standard error per plot is reduced to 16.4 per cent. of the mean.

Next a 4 × 4 Latin Square arrangement is formed by combining 9 of the original plots. Each plot now contains 90 plants. The yields for the 16 plots and the analyses are given below in Table III.

TABLE III

4 × 4 *Latin Square*

297·19	280·75	262·22	259·10
198·32	230·38	246·83	234·99
273·98	291·22	245·81	188·22
230·30	228·38	179·58	225·28

Analyses of variance

Mean yield in lbs. per Plot of 90 plants

Variance due to	Degrees of Freedom	Sum of Squares	Mean Square
Rows	3	7133·3792	2377·7930
Columns	3	4454·1183	1484·7061
Treatments ..	3	1096·8861	365·6287
Error	6	6617·3453	1102·8909
Total	15	19301·7289	1286·7819
Error + Treatments or Error (new)	9	7714·2314	857·1368

Standard error per plot = 29·9 lbs. or 12·2% of the mean

	Z calculated	Z significant for P = 0·05
Rows *v.* Error (new)	0·5101	0·6757
Columns *v.* Error (new) ..	0·2748	0·6757
Total *v.* Error (new)	0·2032	0·5497
Treatments *v.* Error	−0·5521	1·0953

As before the treatment variance is not significant and hence the sum of squares contributed by treatments and the error are combined to arrive at a new error based on higher number of degrees of freedom. On the basis of this error, neither the row nor the column variance is significant. It is further noticed that the standard error per plot is reduced to 29.9 lbs. or 12.2 per cent. of the mean for plots of 90 plants.

3 × 3 *Latin Square*

Finally, a 3 × 3 Latin Square can be formed out of the 144 original plots, each plot having now 160 plants. The yield data with the analyses of variance is given below in Table IV.

Table IV

Yield in lbs. of fruits per plot of 160 plants

501·54	447·59	487·05
455·08	439·00	415·99
415·97	414·12	346·21

Analyses of variance

Mean yield per plot = 435·84 lbs.

Variance due to	Degrees of Freedom	Sum of Squares	Mean Square
Rows	2	11259·5355	5629·7677
Columns	2	2558·6246	1279·3126
Treatments ..	2	1737·0522	868·5261
Error	2	1196·1022	598·0511
Total	8	16751·3145	2093·9143
Error + Treatments or Error (new)	4	2933·1544	733·2886

Standard error per plot = 27·05 lbs. or 6·2% of the mean yield

Tests of Significance

	Z calculated	Z significant for P = ·05
Rows *v.* Error (new)	1·0191	0·9690
Columns *v.* Error (new) ..	0·7250	0·9690
Total *v.* Error (new)	0·5245	0·8993
Treatment *v.* Error	0·1865	1·4722

Now, the variance contributed by rows is significant and the treatment variance is not significant. As before treatment and error variances are combined to form a new error variance. The standard error per plot of 160 plants

and mean yield of 43,584 lbs. is 27.05 lbs. or 6.2 per cent. of the mean yield.

Discussion of results.—It is thus seen that even with an arrangement like Latin Square, the standard errors involved in coffee for plots of sufficiently big sizes, are big enough. Table V gives the standard errors corresponding to the different plot-sizes, with the theoretical errors worked on the basis of the 10-tree plot.

TABLE V

Plot-sizes and standard errors

Plot-size	Mean yield per plot in lbs. of fruits	Standard error		Theoretical standard error in % of the mean
		Actual lbs.	% of mean	
10-tree plot.. ..	27·24	7·01	25·8	25·8
40 ,, ...	108·96	17·83	17·36	12·9
90 ,, ...	245·16	29·28	11·53	8·6
160 ,, ...	435·84	27·05	6·20	6·4

A certain amount of information can be obtained as regards a suitable plot-size that can be employed with the plant material available for field experiments in coffee, from the table. The one prominent character of the figures is the decrease in standard or experimental error with the increase in plot-size. The fall in the percentage error is rapid beyond the 90-plant plot unit and beyond that the fall is not so rapid as the plot-size increases. So that it is evident that the lowest plot-size advisable is anything beyond a 90-plant plot, with the plant material available, for yield figures are obtained from an area which was apparently more uniform in the plants and shade with minimum number of supplies and vacancies than any other area.

In order to reduce the error further at the station which seems to be necessary for most of the experiments, other means, such as increasing the replications, etc., have to be adopted. However, it may be remarked that the size and

the number of replications depends on the accuracy needed for the experiment. If smaller differences between the different treatments are expected, then bigger plots and greater number of replications are necessary.

The heterogeneity of the plant material is so large that the removal of the positional variance has been relatively ineffective in reducing the error. This is in agreement with Beckett's opinion that "experimentation with permanent crops is at a disadvantage compared to annual crops due to the heterogeneity of the material, in that the elimination of positional variance is less successful than in the case of annual crops".

Conclusion.—It is clear from this study that certain necessary measures have to be adopted if field experiments with coffee can yield significant results on the basis of modern statistical methods. As previously quoted (Gilbert) "certain data must be accumulated before precise field experiments can be successfully carried out. The most important data are the individual tree records, uniformity trials, knowledge of plot-size and for precise work standardised material."

The first improvement must be made in the plant material which must be standardised and made homogeneous to the maximum extent possible for otherwise the futility of trying to show small improvements in the yields by treatments, even with moderately big-sized plots, is obvious in view of the large errors present. The variability among the plants in the older areas may also be due to the suspected existence of plants of mixed parentage.

It has been said that the variability of plants raised from seeds is greater than of those obtained by vegetative propagation. According to G. E. Sladden, grafted plots of coffee have the following characteristics: (1) More uniform trees, (2) simultaneous ripening of all trees and (3) uniformity of fruits and seeds. And Ferwerd has compared the merits of grafting with the usual method of propagation by seed. He says that the advantages are uniformity in growth and habit, less variability in yield and the ripening

period is more defined. These are very desirable characteristics in plants from the point of view of field experiments also. Further, younger plants are suspected to show greater variability in yield than older plants. Hence older plants may, with advantage, be chosen for field experiments.

The Twenty-first Annual General Meeting and Field-Day of the Mysore Agricultural and Experimental Union

The Twenty-first Annual General Meeting of the Mysore Agricultural and Experimental Union was held at the Government Experimental Farm, Hebbal, on the 3rd November 1940. According to a resolution passed at the previous General Body Meeting, the Union was registered as a Society under Act III of 1904 and Act V of 1939 and this was the first General Body Meeting held after the incorporation of the Union. The day's programme was divided among three items, (1) the Field-Day, (2) the Business Meeting, and (3) the Discussions.

The Field-Day

Conveyance was arranged for the members who gathered at the Office of the Director of Agriculture in the morning of the day, to take them to the Hebbal Farm. These and the other members who had already reached the place from other directions were taken round the Farm by the Principal of the Mysore Agricultural School and other Officers of the Farm.

Several activities of the Department are now centred at the Hebbal Farm. The fields have been extended, the lay-out of experimental plots have been remodelled, and new crops and cropping systems have been tried as the ideas of improved agriculture have changed and developed from time to time. The Live-stock Section represented of old by the Hebbal Dairy and the Sheep Farm now includes the Dairy, the Sheep and Goat-Breeding Station, the Poultry-yard and the Hatchery. A tobacco barn has been newly built and other additions have been made. The members showed a great interest in all these developments and their visit to the different sections took about three hours from 9 a.m. to 12 noon.

Meals were arranged in the Agricultural School Hostel for all those who stayed on the Farm and the students of the School co-operated with the Staff of the Union in looking after their comforts.

The Business Meeting

The Sheep Expert's Office Hall was placed at the disposal of the Union for the Assembly. Members gathered there at 2 p.m. The Hall was full.

The members approved of the Secretary's Report* for the year presenting the accounts for 1939–40 and also the new Constitution and Rules of the Union, with a few amendments and additions.

The following resolutions were passed by the members assembled:—

1. "The Members of the Mysore Agricultural and Experimental Union convey their sense of profound sorrow at the great loss sustained by the Country by the demise of His Highness the late Maharaja of Mysore, Sir Sri Krishnaraja Wadiyar Bahadur, during whose long rule of nearly forty years, Agriculture in Mysore improved by leaps and bounds and whose solicitude for the welfare of the Mysore Agriculturist has been felt all over the State."

2. "The Members of the Mysore Agricultural and Experimental Union, assembled at the Twenty-first Annual Meeting, most respectfully tender their loyal and humble felicitations to His Highness Sri Jayachamaraja Wadiyar Bahadur, Maharaja of Mysore, on his recent *Pattabhishekam.*"

3. "The Members of the Mysore Agricultural and Experimental Union resolve to congratulate their Vice-President, Professor B. Venkatanaranappa, on the title of *'Rajaseevasakta'* conferred on him by His Highness the Maharaja of Mysore at the last Dasara."

4. "Resolved that the gratitude of the Members of the Mysore Agricultural and Experimental Union be conveyed

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* Issued to members as a supplement to the Journal.

to the Government of His Highness the Maharaja of Mysore, for the assistance so far afforded to the Institution and that a request be made for increasing the Subvention to Rs. 3,000 per annum, so that the Union may cope with its increased responsibilities and be able to render greater service and issue a larger number of copies of the *Journal of the Union* to Village Panchayats, as the *Journal* has become an effective medium for transmission of the benefits of Agricultural Research to the raiyat."

5. "Resolved that the gratitude of the Members of the Mysore Agricultural and Experimental Union be conveyed to the Revenue Commissioner in Mysore for having recommended the Kannada *Journal* of the Union to all the Village Panchayats and request that he may kindly arrange for an annual grant from the Rural Reconstruction allotments for the free distribution of copies of the *Journal* to selected Village Panchayats.

6. Resolved that the Director of Public Instruction in Mysore be requested to kindly continue the patronage of the Education Department and recommend the Kannada *Journal* of the Union to all rural Middle and Upper Primary Schools, so that all such schools may subscribe to the *Journal* which has a special section devoted to the publication of the results of the demonstration of improved methods in thousands of raiyats' fields all over the State. If there is scope for a large number of subscribers arrangements will be made for an article in every monthly of the *Journal*, addressed to Middle School students on the elements of improved Agriculture."

Elections were then held to the Committee of Management and to the Board of Editors. The members constituting the Committee of Management and the Board of Editors respectively are as follows:—

Committee of Management:-

(1) Mr. T. G. Rama Iyer, B.A. (*President*).
(2) *Rajasevasakta* B. Venkatanaranappa, M.A. (*Vice-President*).
(3) Mr. M. J. Narasimhan, B.A.

(4) Mr. S. Venkataswamy Gowda.
(5) „ M. S. Ramachandra Rao, B.A., B.L.
(6) „ B. Shankara Rao Badami, M.A.
(7) „ G. Venkataramaniah.
(8) Major C. B. Oakley, V.D., A.M.I.M.E.
(9) Mr. T. Lakshmana Reddi.
(10) „ B. V. Venkatacharya, B.Sc. (Agri.).
(11) „ Gowda Shivappa Kalpanahalli.
(12) „ M. Vasudeva Murthy, B.Ag. (*Secretary*).

Board of Editors:

(1) Mr. M. J. Narasimhan, B.A. (*Chief Editor*).
(2) „ M. G. Singarachar, B.A., A.C.E.
(3) „ T. V. Subramanyam, Dip. in Agri.
(4) „ S. D. Achar, G.B.V.C., P.G. (Punjab).
(5) Dr. B. T. Narayanan, B.A., Ph.D.
(6) „ L. S. Dorasami, M.Sc. (Lond.), Ph.D. (Lond).
(7) *Rajasevasakta* B. Venkatanaranappa, M.A.
(8) Mr. B. V. Venkatacharya, B.Sc. (Agri.).
(9) „ S. V. Sharma.
(10) „ K. H. Sreenivasan, M.A., B.Sc. (Edin.).
(11) „ C. V. Ramiah.
(12) „ K. M. Gururaja Rao, L.Ag.
(13) „ M. Vasudeva Murthy, B.Ag. (*Secretary*).

Discussions

The items on the programme of discussions were, (1) Inter-cropping, (2) Sugarcane, (3) Paddy, (4) Tobacco, (5) Judicious manuring of crops, and (6) Cotton. The Director of Agriculture commenced the discussions.

In dealing with paddy to which, he said, first consideration was due, he explained that there was a large import of rice at present into the State. The deficit indicated by it has to be made up. The area under the crop does not admit of much extension. All attempts should therefore be made to increase the yield per acre. New strains of paddy would enhance the yield by 12 to 15% and in some cases there has been a 50% increase. Strains S. 661 and S. 684 have

proved to be good *hain* season varieties and S. 705, a good summer season variety, so far as the present selections go. Next to selection of good varieties, judicious manuring would help to increase the crops considerably.

With respect to cotton also a large deficit is being felt. The Department has evolved good strains for both the black cotton area and the red soils. M. A. II is a very good yielder and has been spoken of well in the market also. It grows well under irrigation and recent experiments indicate the possibility of taking it up in the red soils as an inter-crop where ragi is grown.

Taking up sugarcane, the Director of Agriculture explained that though H.M. 320, the variety that is distributed on a large scale at present has given very satisfactory yields all over the State, H.M. 661, a strain recently evolved and tried in the statistical plots promises to be even better.

With regard to ragi also there are a number of strains which can be recommended for earliness and high yield.

Subvention Farms and Demonstration Plots are introduced to help the raiyats to realise the benefits of these improvements and adopt them in their farm practice.

The cigarette tobacco cultivation, the Director explained, is spreading in various localities in the State and as there is a large demand for Mysore tobacco, it can be adopted as a remunerative crop.

The questions raised by the members showed that one of the chief considerations with them was the problem of marketing for which State help was necessary. They greatly appreciated the recommendations regarding the improvement of agriculture.

M. V.

SELECTIONS

Honey as a Stimulant to the Rooting of Cuttings

BY

R. W. Oliver*

The author has found that honey has a definitely stimulating effect on the rooting of cuttings of *Thuja occidentalis pyramidalis,* and of chrysanthemum. The best treatment consisted in standing the cuttings in a 25 per cent. solution of honey for 24 hours before planting. A higher percentage of cuttings rooted, and there were more roots per cutting; the response, moreover, was only very slightly less pronounced than that which followed most favourable hormone treatments. The substance or substances stimulating root formation have not yet been isolated from the honey.

—*Horticultural Abstracts,* Vol. 9, No. 3.

Agricultural Products as Insecticides

BY

R. C. Roark§

The following is based on the author's summary: About 100 million dollars' worth of insecticides and fungicides are employed annually against insect and fungous pests causing an annual loss of three billion dollars in the United States. Although the materials now largely used for this purpose (compounds of arsenic, fluorine, lead, copper and sulphur) are of mineral origin, vegetable products are being used to an increasing extent. This is because many organic compounds are more toxic to insects but less toxic to man than are lead arsenate and other inorganic poisons. In addition to organic insecticides that exist naturally in plants, such as nicotine, anabasine, the pyrethrins, rotenone, groundnut oil and other plant oils, products derived from coniferous trees, such as pine-tar oil, are also valuable insecticides, and synthetic compounds derived from oils, alcohols, furfural and other promising plant products are now coming into commercial use as insecticides. It is conjectured that in the future insecticides will be mostly organic compounds obtained from plants now regarded as worthless weeds or synthesised from products of plant origin. The possibilities of constructive chemical research in this field are boundless and should result in numerous products of great economic value.

—*The Review of Applied Entomology,* November 1939.

* *Soc. Agric.*, 1939, vol. 19, pp. 586–8.
§ *Industr. Engng. Chem.*, vol. 31, pp. 168–71, Easton, Pa., 1939.

Napier Grass

Napier Grass (*Pennisetum purpureum*) Improvement

As was reported in 1937, eleven selected strains of Napier grass were inoculated with the organism (*Helminthosporium ocellum*) causing eye-spot in Napier grass, and eleven of the twelve original selections were declared immune to the disease by the Department of Plant Pathology. In addition to these, 81 other selections were under observation during the year 1937.

Four strains of the 12 original selections which represent the main types found in the group, together with seven of the most promising selected from the group of 81 other strains, have been planted in a strain test to determine relative yielding value. Limited planting material of several of these most desirable strains of napier grass has been distributed.

More than 3,000 plants were grown in 1937 from seeds and planting material collected from the Everglades. Seventy-one of these were selected for further study. Each plant, root-clump, was divided and planted in five replications for comparative yield and observational records.

The Result of Selfing in Napier Grass.—In the autumn of 1936 a number of Napier grass heads were bagged and self-fertilized. This self-fertilized seed was sown in greenhouse plots in the winter of 1937 and 1938, and the plants transplanted to the field in April. Although the parent plants from which each group of seed heads were obtained were from the same root cutting the seedlings from the self-fertilized seed showed variations from large, heavy-stemmed plants to small fine-stemmed plants with other variations of growth habits. This indicated that Napier grass is very widely cross fertilized and that wide variations may be expected from seedlings, thus if it is necessary to go into the improvement programme further, fertilization of the flower becomes an important factor to consider.—(*Geo Ritchey and W. E. Stokes.*)

A Study of Napier Grass (*Pennisetum purpureum* Schumach) for Pasture Purposes

A study of Napier grass for grazing purposes is a co-operative project conducted by Animal Husbandry and Agronomy Departments. Suitability of Napier grass for supplementary and continuous pasturage for both beef and milk production is to be determined.

Fifteen acres of Napier grass, divided into five three-acre blocks, was planted in March 1937. The rows were spaced eight feet apart and the divided root clumps (rhizomes) of Napier grass were spaced two feet apart in the row.

The grass is being grown under a rather high fertility level. An initial application of 400 pounds per acre of a 5-7-5 fertilizer was made in the row at time of planting. Seventy-five pounds per acre of nitrate of soda was applied as a side-dressing after the grass had been grazed by cattle.

Grazing is rotated on the five three-acre fields. Grazing is started when the grass is about four feet high and continued till all the leafage has been consumed. Each field is stocked so that the feed will be consumed on one field in approximately seven days. This allows twenty-eight days between grazing periods.

Grazing with steers was started on July 28, 1937, and continued until October 4, 1937. The carrying capacity was 1·6 steers per acre for each growth day of Napier grass. The average gain was 1·45 pounds per steer per day. An acre of Napier grass produced 2·32 pounds in terms of beef per day for 1937 or 179 pounds of beef on foot per acre for the grazing period of 69 days.

Two additional areas of Napier grass were planted in March 1938. One of these areas is to be used to determine beef cattle gains when supplemented with cottonseed cake. The other planting is to be utilized by dairy cows to determine its suitability for milk production. —(R. E. Blaser, W. E. Stokes, A. L. Shealy and W. G. Kirk.)

A Study of Napier Grass (*Pennisetum purpureum*) for Pasture Purposes—Animal Husbandry Phase

Grade yearling Hereford and Aberdeen-Angus steers were used to measure the carrying capacity and nutritive value of five 3-acre lots of Napier grass. Fifteen steers were started on test July 28, 1937. The number of steers was increased to 30 by adding five animals at different times throughout the 68-day test period. The steers had access to one 3-acre lot at a time. When the leaves and a considerable portion of the stems were eaten the steers were moved to a second lot. By pasturing each lot in rotation it took approximately 35 days to graze the 15 acres of Napier grass. During this period the Napier grass in Lot 1, which was pastured first in the rotation, had grown sufficiently to be grazed a second time and Lot 2 was ready to be grazed when Lot 1 was finished. Thus there was a continuous supply of succulent feed available.

The steers had access at all times to the following mineral supplements, (1) common salt, (2) steamed bone meal, and (3) "salt sick" mixture, which consists of 100 pounds common salt, 25 pounds red oxide of iron and 1 pound copper sulfate

The average daily gain per steer per day for all steers was 1·45 pounds. Each acre of Napier grass provided feed for one steer on an average for 124 days and produced 179·7 pounds of gain.

Refer also to Project 302 in *Report of Agronomy Department.*- (W. G. Kirk.)

The Digestibility of Fresh Napier Grass

A planting of Napier grass was made in March 1938 on an area adjacent to the Nutrition Laboratory. It has been irrigated and fertilized and is ready for a preliminary cutting, that forage of a uniform stage of growth may be obtained for the digestion trial scheduled to start early in August.

Four steers will be used in the digestion trial, which will extend over a 30-day period. The first 10 days will be preliminary and the last 20 days will be experimental. The grass will be cut twice daily in a manner to stimulate grazing and fed to the animals in the stalls. Manure collections will be manual. The standard methods for this type of trial will be used.—(W. M. Neal, P. T. Dix Arnold and R. B. Becker.)

—From the *Golden Anniversary Report for the fiscal year ending June* 30, 1938, *Agricultural Experiment Station, University of Florida, Gainesville, Florida.*

Nutrition and Reproduction

BY

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The maintenance of regular and healthy reproduction coupled with a sound breeding policy is clearly essential to the development of successful animal husbandry. Until recent years the major causes of reproductive troubles were commonly sought in the field of disease, but conclusive evidence is now available that in very many cases the basic causative factor primarily arises from faulty nutrition. The effects of such factors, moreover, are not necessarily exercised directly upon the sex organs, but may affect their activities only indirectly through the establishment of abnormalities in other parts of the body whose healthy co-operation is essential to the optimum working of the reproductive processes.

That general bodily condition may react upon reproductive efficiency has long been known to observant breeders. Extremes of leanness and fatness must be avoided. The half-starved animal, whether male or female, is likely to be slow in arriving at puberty and of low breeding efficiency thereafter. The female in such condition may for a time produce healthy offspring, but only through incurring a strain upon her body that may soon cause the production of dead

or weakly offspring and permanent damage to herself. The underfed male will show his weakness in reduced number and vigour of the sperms. At the other extreme, the detrimental effects of over-fatness are revealed in the widespread experience that in both sexes the maintenance of animals in "show" condition for more than short periods is generally accompanied by low fertility.

Under-nutrition may arise from a general deficiency of energy supply or from deficiency of one or more of the specific essential factors, such as vitamins or minerals, or from the combined effects of more than one deficiency, and the nature of the reaction upon reproductive activity will vary with the character of the nutritional defect. In the female an effect that seems to be common to all types of nutritive deficiencies is a disturbance of the œsterous cycle, leading to irregularity or in severe cases to actual cessation.

Energy Requirements.—The minimum energy requirement for reproduction in the female is obviously that represented by the energy stored in the form of new tissues in the growing fœtus and its membranes, in the enlargement of the uterus and the development of the mammary glands. To estimate the actual energy requirement, however, this minimum must be increased, since even under the most favourable conditions it is hardly possible for the whole of the available energy that is applied to the reproductive process to be stored up in the new tissues. In other words, we must provide not merely for the material produced but also for the work of reproduction. Each of these items, which together form the total energy requirement, will vary at different stages of the gestation period.

That the rate of storage of energy in the fœtus and other uterine products rises steadily as gestation progresses has been well demonstrated in studies with young sows at the Illinois Agricultural Experiment Station. In these studies it was found that with a sow producing a litter of 8 pigs the daily storage of energy rose from less than 2 calories in the first week to 272 calories in the sixteenth week of gestation. Similar increases were also recorded in the storage of protein and mineral elements. For the whole period the average daily storage of energy was 104 calories, and assuming that the additional storage of energy in the growth of the mammary glands would not exceed 10 per cent. of this figure, an estimate of an average daily requirement of 115 calories of net energy to cover the specific needs of reproduction was arrived at. When this is compared with the net energy requirement for maintenance of gilts of the weight used in these studies (200 lb.), which was put at 2,000 calories, it will be seen that the extra energy requirement of the in-pig gilt as compared with the "empty" gilt amounts to no more than 5 or 6 per cent., and even at its highest point in the closing week of gestation when it may

have risen to 300 calories, this represents but a 15 per cent. addition to the basic maintenance requirement. If these energy figures be converted into terms of the corresponding weights of digestible nutrients, the ratios will remain much the same and we may conclude that as far as extra energy supply is concerned the additional requirements for pregnancy of the sow are trivial in the early stages of gestation and at no stage are likely to exceed 20 per cent. of the basic maintenance requirement. With longer period of gestation of the cow, the extra energy requirement in proportion to the size of the animal is probably even smaller.

These computations leave out of account, however, the bodily condition of the mother herself, and if this is low at the onset of pregnancy it will clearly be advisable to feed on a more liberal scale until the desirable state of bodily fitness has been attained. This is all the more important since some draft upon the reserves of the body is almost certain to be made, even with abundant food supply, to sustain the milk flow subsequent to parturition, when it reaches its maximum level.

A further point to keep in mind in connection with these estimates of food (energy) requirements is that they assume that the ration is adequate with regard to all other essential factors. Should there be a deficiency of protein or phosphorus, for example, then probably a greater amount of food will be required to secure the same level of storage of energy. The nature of the ration requires separate consideration, therefore, apart from the question of energy supply.

Protein Requirement.—Bearing in mind that the dry substance of the fœtus and other products of gestation is rich in protein, it follows that the trend of protein storage with advance of gestation will be similar to that of energy, small in the early stages and rising to a relatively high level at the end. Thus, in the Illinois studies referred to above the daily rate of storage of crude protein rose from 0·5 grm. in the first week to 33 grm. in the sixteenth week. This is a far smaller relative increase than that found in respect of energy storage, which is to be expected since, as the fœtus develops, an increasing proportion of the retained energy is stored in the form of fat.

Over the whole period the average rate of protein storage was 14 grm. per day,* which may be raised to 16 grm. to allow for protein stored in the increase of mammary gland. As to how much digestible protein should be included in the food supply to provide

* This figure agrees well with that of 12·5 grm. obtained by Evans in experiments at Cambridge.

for this storage, this will depend upon the "biological value" (or "quality") of the food protein. If this be assessed for common types of rations at 50 per cent., the average daily requirement of digestible protein in the food to secure an average storage of 16 grm. would be 32 grm. Similarly, to provide for the 35 grm. daily storage in the last week of gestation about 70 grm. of digestible food protein will be needed. According to American estimates the pig of 200 lb. live weight requires for maintenance about 100 grm. of protein per day. German estimates give the much lower figure of 60 grm. but even taking the higher figure it will be seen that the additional requirement for food protein imposed by pregnancy is no less than 32 per cent. on the average of the whole period and 70 per cent. in the closing stage of gestation. Although, therefore, the total food requirement during pregnancy as indicated above may be but little increased, the protein requirement is substantially increased and therefore the composition of the ration must be adjusted by reducing the cereal fraction and increasing the protein-concentrate fraction, to ensure the necessary increase of protein supply. The same principles apply to other classes of live-stock, but where the rate of development is slower the relative increase of protein supply required will be less. Thus, Maynard estimates that the maintenance requirement for protein for the cow may be increased during gestation by an average of 17 per cent. over the whole period, or 40 per cent. in the closing stage.

These are probably under-estimates of what is *desirable* since here again, as also for energy storage, regard should be had to the desirability of enabling the parent to store up a reserve of protein in her body, apart from the bare needs for reproduction, in order to provide some insurance against the drain to which she may be exposed later when the heavy demands of lactation have to be met.

Vitamin Requirements.—Despite a considerable amount of research, the precise significance of vitamin supply for reproductive efficiency is still not clearly defined. Only for vitamins A and E does there seem to be a clear case for postulating that the maternal diet must include extra amounts to cover any specific requirement for reproduction. For the welfare of the mother herself the whole range of vitamins may be of importance, and certainly the A and D vitamins, whilst a liberal supply of these vitamins to the mother makes possible the accumulation of reserves in the fœtus, which will be valuable in the early stages of post-natal life. That there is a specific requirement for vitamin D for reproduction would seem probable, but conclusive evidence as to this has not yet been obtained, especially as regards farm animals.

That an adequate supply of vitamin A is essential for efficient reproductive activity has been established for both sexes. In the

male a deficiency of this vitamin quickly induces a marked lowering of fertility. In the female the first sign of vitamin A deficiency is commonly the development of irregularity of œstrus, which ultimately may cease entirely if the vitamin deficiency is very severe. If fertilization takes place, the gestation may be prolonged and terminate in difficult parturition; the placenta will often be abnormal and the incidence of fœtal death and resorption, or of abortion, will be increased. These effects arising primarily from placental injury are said to differentiate cases of vitamin A deficiency from fœtal death due to deficiency of vitamin E which is occasioned more directly by defects in the fœtal tissue itself. The diagnosable symptoms of vitamin A deficiency vary somewhat according to the species of animal and the severity of the deficiency.

Little is known as to the minimum requirements of vitamin A for reproduction, but there is evidence that they are at any rate greater than those for maintenance. The simplest practical safeguard against deficiency of this vitamin lies in the supply of leafy green stuffs, either fresh or artificially dried. Where this is not available, or with animals, such as the pig, that can only digest relatively small quantities of roughage, the inclusion of yellow maize in the ration will be helpful. There is evidence, however, that pig-feeding rations, even when relatively large proportions of yellow-maize are included, are often barely adequate in supply of vitamin A unless either a store of the vitamin has been built up in the animal during the pre-natal and early post-natal periods, or some additional good source of the vitamin, such as greenstuff or cod-liver oil, is added to the ration. As to the former alternative, experiments at Cambridge and elsewhere have demonstrated that only a very small fraction of the vitamin A of the maternal food supply can be stored up in the offspring so that with a rapidly-growing animal like the pig the most liberal pre-natal supply of the vitamin to the mother will not for long safeguard the offspring against deficiency in the post-natal food supply.

The basic need for vitamin E for reproductive efficiency has been demonstrated, but there is little evidence as yet that breeding troubles due to deficiency of this factor are met with more than very rarely in farm practice. Nor, indeed, is it to be expected that this class of trouble would be often met with in view of the supply of the vitamin in greenstuffs and the germ of cereal grains. Should the exigencies of flour milling, however, lead to a greater removal of the germ for the "offals" than is as yet customary, the possibilities of vitamin E shortage in breeding stock kept indoors with little or no greenstuff or unmilled grain would need to be examined.

Mineral Requirements.—The general importance of an adequate supply of mineral elements for the building-up of the developing

fœtus is obvious. Calcium and phosphorus are essential for bone formation, alkalies for the proper functioning of the body fluids, iron for the production of the necessary hæmoglobin in the blood, iodine for the efficient working of the thyroid gland, and other mineral elements for other specific purposes. There is little possibility with these mineral requirements of off-setting a deficiency of one element by a surplus of another of similar character, say of potassium by sodium.

For the purposes of energy supply, carbohydrates, fats and proteins are to a large extent mutually replaceable, but in regard to mineral supply the functions in the body of each particular element are largely specific and can therefore only be met by the supply of that element in the food.

Judged in terms of quantity the most spectacular mineral requirement for growth, and therefore for reproduction, is that for calcium and phosphorus, since these form so large a part of the structure of the bones. The magnitude of this requirement explains also why deficiencies of calcium and phosphorus are more frequently the cause of trouble in practical animal husbandry than any other form of mineral shortage.

The direct incidence of deficiency of calcium or phosphorus on reproductive efficiency has been conclusively demonstrated by experimental work in many parts of the world. As an example, the classic work of Theiler and his associates with cows on the phosphorus-deficient grazing areas of South Africa may be quoted. When the grazing was supplemented by bone meal or other phosphorus concentrates the calf crop was about 60 per cent. greater than when no such supplement was given. Similar effects upon fertility also accompany calcium deficiency, which causes an increase in the number of progeny born dead or weakly.

Over the world in general, calcium deficiency is probably less widespread than phosphorus deficiency, but there are many areas, including a large part of Britain, in which the position is reversed. In housed animals fed mainly on grain and other concentrated foods it is also more often the supply of calcium than of phosphorus that needs special attention.

The effects of shortage of these elements on reproduction are the more insidious through the gradual character of their development, since for a time, which may be prolonged, the deficiencies of the food may be made good by depletion of the supplies of calcium and phosphorus in the maternal skeleton. Even with a continuous deficiency, therefore, little effect may be apparent at the first, or even at the second pregnancy, and when eventually it does appear the general tendency will be to look for the cause in some recent change of diet

or treatment rather than in the long-continued (but unsuspected) dietary mistake. The unwisdom of allowing a drain upon the mineral reserves of the material body during the gestation period becomes actual folly when it is remembered that this period is followed by the period of milk production, in which for a time some further depletion of the maternal mineral stores is almost inevitable even with a liberal supply of minerals in the food.

It is difficult to arrive at reliable data for the calcium and phosphorus requirements of the pregnant animal since these must cover not only the amounts actually stored in the contents of the uterus but also the maintenance needs of the mother, who should indeed receive more than this in order to enable her to build up reserves in her bones with which to meet the subsequent strain of lactation. As to the actual storage in the growing fœtus, the data obtained in the American studies with pigs referred to above indicated that about 95 per cent. of the calcium and 90 per cent. of the phosphorus were stored up in the second half of pregnancy, and no less than 60 per cent. and 50 per cent. respectively were stored up in the last three weeks. It would seem, therefore, to be more particularly in the later weeks of pregnancy that attention should be given to the adequacy of the supply of these two mineral elements. On the other hand, results obtained by Evans at Cambridge indicated that, even with a liberal supply of calcium in the food, the enhanced requirements of the fœtus in the later stages of pregnancy were largely drawn from the maternal reserve, so that the wiser plan may be to give calcium liberally in the first half of the gestation period in order to ensure that this reserve is fully developed when it is needed, rather than to rely upon direct assimilation from the food at the time when the need is greatest. The same applied to the storage of iron except that in this case the rate of increase of storage increased more gradually from start to finish, although about 80 per cent. of the total was stored in the second half of the period and nearly 40 per cent. in the last three weeks.

In other American studies the conclusion was reached that the ration of pregnant sows should contain not less than 0.4 per cent. of calcium, or say 0.3 per cent. rising to 0.5 per cent. with rather less phosphorus. For gilts the proportion would need to be a little higher to cover the gilt's own growth requirements.

As regards ruminant animals, with their longer period of gestation, the daily requirement of minerals is less in proportion to body size. Thus, in the ewe it is estimated that 0.22 to 0.35 per cent. each of calcium and phosphorus in the daily ration will be adequate. In the cow a still lower proportion, say 0.15 to 0.25 per cent. is probably adequate for maintenance and reproduction, but here the

estimation of the requirements for the needs of production is complicated in the first pregnancy by the simultaneous need for the purposes of growth of the heifer, whilst in later pregnancies a still greater complication arises if, as is usual, milk production is continued through the greater part of the new gestation period. In practice, therefore, it is hardly possible or indeed necessary to discriminate between the requirements for the various needs which together make up the total requirements. A rough standard which, judged by American data, will probably not be far wide of the mark for average conditions, can be arrived at by taking a minimum requirement of 0·10 per cent. each of calcium and phosphorus in the dry matter of the food for the "empty" dry cow, increasing this by 0.07 per cent. for the dry in-calf cow and by a further 0.07 per cent. for each gallon of milk. On this basis, the cow of average size, in-calf and giving 2 gal. of milk daily would need in her daily ration about 0.3 per cent. each of calcium and phosphorus.

The requirement for other mineral elements need only be dealt with briefly since it is probably only rarely in ordinary breeding practice that actual deficiency with regard to them arises.

It is true, for example, that the need of the pregnant animal for iron is probably twice or thrice as great as the maintenance requirement, but unless the animal is kept under highly artificial conditions, such as are for many reasons undesirable for breeding stock, it is unlikely that even this enhanced iron requirement will not be met by the ordinary food supply. The risk is certainly greater with a prolific quick-growing species like the pig than with slower-growing species, and for the in-pig sow, without making any nice calculations as to iron supply, it may be worth while to enrich the dietary slightly with iron on the off-chance that some little of it may be stored in the young pigs, which thereby may be better equipped to avoid the post-natal risks of anæmia.

The only other mineral element that perhaps needs special mention is iodine, but as to whether deficiency of this element is likely to be at all common in practice it is difficult to obtain clear guidance. Since iodine is an essential factor in the activities of the thyroid gland, which include an intimate influence upon the processes of reproduction, it is obviously very important that there should be no risk of shortage of iodines in the breeding animal. The evidence from practical feeding experiments with iodine supplements to ordinary rations is very conflicting, and certainly does not as yet warrant any general recourse to iodine supplements for breeding stock. A deficiency of iodine so pronounced as to affect reproduction seriously will almost certainly establish a goitrous condition in the parent animal, and where such condition can be diagnosed an increase in

iodine supply is clearly required. In the light of existing information we are inclined to agree with Maynard that "there is no conclusive evidence that the feeding of additional iodine to breeding animals is helpful except in the specific situations where goitre is occurring, or that it has any benefits other than goitre prevention. Since the danger of over-dosage with iodine is a real one, it seems wise to restrict its use to the prevention of goitre and related troubles in areas where they otherwise occur, until positive benefits for other purposes have been clearly proved".

Finally, a word may be said as to the possible need for a supply of salt to the breeding animal. No information is available on this point, but since there is evidence that deficiencies of salt supply may arise in respect of quick-growing animals like the pig and chicken it may perhaps be as well to keep in mind a similar possibility in regard to pre-natal growth, although in this case the maternal body will probably provide an adequate regulator of supply to the uterus, even on a salt-deficient diet. It is plain commonsense, however, that a deficiency which can be foreseen should be avoided.

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On Animal Breeding*

BY

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Objectives.—The purpose of animal breeding is to meet a social demand for some particular commodity or service, *e.g.*, an animal product of a certain kind and quality, an animal so constructed as to be able easily to perform a certain task, or so decorative or quaint as to please.

The objective in animal breeding is the creation and maintenance of types which, in their characterizations, are in complete harmony with their destinies—the purposes for which they are bred. But since every detail of structure and function is the end-result of the interplay, during the individual's development, of heredity and environment, it follows that the breeder is concerned not only with the type and destiny of his animals but also and at all times with their habitat, the conditions under which they live. Type, habitat and destiny must always be

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harmoniously related; each reacts with and upon the others, and any considerable modification of any one of them must necessarily be followed by repercussions of equal magnitude among the rest. The purpose of breeding must be reasonable, not merely economically but also and especially biologically; the environment must be optimum, free from all agencies, living and non-living, which cause defect and derangement, and such as encourages the full expression of all advantageous inborn potentialities; the type must be the ideal, that most easily able to profit fully from the optimum environment provided and to yield the commodity or service demanded of it.

Since from time to time and from place to place social demands change and vary, the breeder is set the task of maintaining either a diversity of types, each harmonized to a particular habitat and/or destiny, or else a 'flexible' type which by modifications in husbandry and/or breeding practice can quickly be remodelled.

Since also, and at the present time, animal stocks are maintained in places and under conditions which are such as to make the biologically optimum environment unattainable, the objective in animal breeding commonly comes to be the creation and maintenance of animal types that are in harmony with the best environment which, under the conditions, it is economically possible to create.

At the present time, for reasons which are rooted in economic necessity, animal stocks are being maintained in habitats which are in every respect incurably harsh and entirely unsuitable. In the future, when reason controls our activities, perhaps animal-breeding planning will ensure that animals are bred where they most easily breed and thrive. For the present we must content ourselves with the production of types that give the best performance under given conditions, whilst all the time we strive to improve these conditions.

If in any given region a uniform environment exists, then as this approaches the optimum there will be a reduction in the number of types that are needed, and the few that remain will show uniformity and will become relatively fixed, whereas in a region which includes a variety of environments a lower degree of uniformity and a greater degree of adaptability will be required.

At all times and in all places the breeder must maintain a high reproductive rate and a low mortality rate, for he is concerned not only with productivity of his stock but also with its reproductivity and its viability.

It is recognized that policies of livestock improvement necessarily involve synchronized improvement in destiny (marketing), in habitat (husbandry, including nutrition and disease prevention), and in type (the genetical constitution of the stock, breeding systems, standards). Though on occasion specialists may consider these different aspects

of one and the same problem separately, the breeder himself in practice can never hope to disentangle them, nor should he wish to do so.

These are the views of a biologist who sees the world through the windows of a laboratory. It may be that the windows distort that which is seen, or protect the onlooker from the fierce winds of financial anxiety. Be this as it may, the fact remains that the breeder is also an experimental biologist, and that his success or failure is determined less by his financial acumen than by his biological expertness. This being so, it may be mutually profitable for biologists to commune.

The Fowl.—To give point to these views any one of us could choose a convenient example. I propose to use the fowl, because it has been my collaborator in many an experiment; but the fowl is merely an illustration of all livestock. Society demands a 2-ounce egg (with a white shell and at a certain price). Thus the purpose of poultry-breeding for egg-production is the provision of this 2-ounce egg. But in order to meet this demand, and in so doing to secure an adequate reward (according to the standards of our own society), the breeder has to create and maintain a stock of fowls which will mature in less than seven months (*i.e.*, he has to be able to control growth-rate, bodily maturity, and puberty); that will convert say 95 lb. of food into 200 such eggs (he is concerned with the genetical and physiological aspects of efficiency of food-utilization and of fecundity); that will show a fertility-rate of at least 85 per cent. (he must know a great deal about the genetical and physiological aspects of fertility; that will show a mortality-rate of not more than 10 per cent. (disease-resistance, disease-prevention, viability); and that is of such a quality that about two-thirds of the stock can be profitably retained for a second year of production (he must know all that is known concerning the factors affecting the duration of productive life). These are the objectives in breeding, and be it noted every one of them must be gained and held contemporaneously if the breeder is to build a type that is in harmony with its destiny.

The demand for a 2-ounce egg is reasonable, for it has been shown that the hen can produce 200 or more of these without harm to herself or to her progeny. The objectives are all concerned with biological variables, relating to which a considerable body of scientific knowledge exists. None of them refers to any particular breed trademark, for the breeder of utility poultry at least knows that there is no such thing as the best breed though, of course, he will quite rightly maintain that a certain type (a certain constellation of genetic characters which may or may not include the few superficial characters of a particular breed) is best suited to a particular habitat and for a particular market. In fact 'breed' no longer possesses any considerable importance to the utility breeder; good looks are less important

than are the individual's own record of performance, the record of its relative (pedigree), and the record of its offspring (progeny test). Brothers and sisters, and cousins and aunts are important people in the poultry world.

So many are the qualities that the breeder must maintain in his stocks, so varied are the mechanisms that underlie them, and so incomplete is our knowledge of them, that the general public should not be surprised to find that the breeders have not yet succeeded in doing all that they must do before the industry is placed on a satisfactory basis. It is probably correct to say that the average egg-production per bird per year is around 80 eggs, and that these do not average 2-ounce in weight; that about 30 per cent. of all the eggs that are incubated fail to yield viable chicks; that the mortality among pullets is of the order of 20–80 per cent.; and nearer 80 than 20; and that stocks must continuously be replaced for the reason that the duration of productive life is so brief. Productivity, reproductivity, and viability are all far removed from what they must be before poultry-breeding can be a profitable and pleasant occupation for breeders as well as for bureaucrats.

It is now recognized that, for a variety of reasons, the affairs of the poultry industry must become the concern of the State. The individual breeder and his organizations are not competent to deal with the complicated problems of disease-prevention, for example, and so these are now to be tackled and solved by a Veterinary State Service. The fowl is about to make its dramatic entrance into the veterinary curriculum; heretofore it has died miserably in its millions because pets have been rated higher than producers. Furthermore, professional scientists by the dozen are being employed to investigate those problems of husbandry, nutrition, and breeding which, for obvious reasons, cannot possibly be properly examined by the breeders themselves.

Possibilities of Genetic Improvement.—The geneticist should be well content to be provided with the opportunity for using the fowl as experimental material. It is relatively cheaply maintained, its matings can be controlled, generation succeeds generation fairly rapidly, and it has numerous offspring. Moreover, the characters, the mode of transmission of which is to be studied, are on the whole definite and easily recognized. In livestock generally it is the very indefiniteness of the characters to be studied, and the lack of knowledge concerning the forces affecting their expression, that make genetical experimentation so hopeless. It is very doubtful indeed that serious genetical investigation of meat qualities can be profitably undertaken until the work of Hammond has been greatly advanced

and extended. It is useless to attempt to make a genetical study of the price of a pound of beef. Before genetical work can proceed the characters to be studied must be accurately described. Moreover, genetical work demands large numbers of animals, and so the geneticist waits upon further developments in the techniques of artificial insemination. Walton and Hammond are, by their work creating the possibility for useful genetical experimentation with the larger domesticated animals in the near future. When the kind of work that Hammond and his colleagues are doing has advanced we shall be in a position to know how far the animal stocks we now possess are capable of being modelled by husbandry into the desired types. If they can be so modelled, then it will be revealed that they are in this respect genetically satisfactory; if not, then by the application of genetical methods appropriate types must be created. We shall know the limits of modifiability and shall have a much clearer notion of what is genetic in these qualities of economic importance.

It will now be seen that there is an inherent difficulty in the conception of the ideal type having its being in the optimum environment. So many qualities are demanded (for example, high reproductive rate, a rapid growth-rate, tolerance to certain important deficiencies) that it seems very unlikely that one and the same environment can possibly be optimum for the full expression of all of them. Thus the optimum environment for high milk-yield might prove to be far removed from the optimum for a high degree of resistance to disease. However, on general grounds, it is reasonable to hold the view that it is possible, by appropriate methods, to bring together into one and the same hereditary constitution the genes for any combination of characters that have been shown to be genetic. But whether or not the characters corresponding to these genus can be fully expressed by any individual possessing them all, is a question that can only be decided by further experimentation. Physiological incompatibilities may prevent the creation of types exhibiting all the desired qualities expressed to the maximum degree. If this should prove to be so, then either the standard of the ideal must be modified or other means of equipping the types with all the desired qualities must be devised.

In the meantime the geneticist has his part to play in helping the livestock industry to concentrate on as small a number of objectives as possible, to rid itself of standards that are based on false methods of evaluating merit, and to develop better criteria for measuring and evaluating livestock and its products. He must also, and at all times, plead that comprehensive schemes of inbreeding should at once be launched for the purposes of genetical analysis and purgation of the stock, and of providing genetically satisfactory material for use in nutritional and other experimentation.

Whilst the methods and practices of the past have accomplished much, giving us the fine breeds of to-day, they seem to be reaching the limits of their usefulness. The past has been dominated by standards that seem now to be more or less unreal, sometimes even misleading, and commonly disregardful of the qualities that really matter—productivity, reproductivity and viability. At the present time we have not disentangled the effects of the environment from those of heredity and so have no knowledge of the importance of either. Without such knowledge we cannot know whether modifications in husbandry or alterations in constitution offer the quickest and soundest means of further improvement.

We are unadventurous in breeding, breeders from necessity, for no private individual in our Society can afford to undertake experimentation that is certainly costly and probably in conflict with his own self-interests; nor will the State, because those who guide our destinies are, for political reasons, more inclined to encourage projects which promise information concerning the possibilities of improving nutrition, general husbandry, and of lowering the incidence of disease by the provision of sera and vaccines. While these are proceeding, and while the standards of the ideal are being re-fashioned and trustworthy yardsticks constructed, the job of the geneticist should be the creation of inbred stocks. Inbreeding to the livestock industry is what track-racing is to the makers of motor-cars. It is the test of constitution, the revealer of hidden faults, the demonstration of ability beyond that ordinarily required. Through inbreeding, strains equipped with vigour and purged of all weakness can be provided for breed-improvement programmes of the future. In order to know what underlies high milk-yield and high egg-yield we must have true-breeding, low-yielding strains. Furthermore, it is not improbable that many of the ideal types of the future will be first crosses between two distinct inbread strains of the same breed.

Though the animal geneticist must wait upon developments in physiology, veterinary science and husbandry before he can hopefully engage in large-scale experimentation with the bigger animals, even now, were he encouraged, he could make contributions of importance. It is established, for example, that in one and the same stock of laboratory animals families differing constantly and widely in respect of growth-rate, weight-for-age, and in efficiency of food-utilization can be developed. There is no doubt that these characteristics, so important in livestock economy, are profoundly affected by heredity, and that they can be manipulated by the application of genetical principles. The correct breeding procedure for the production of similar strains of animals of economic importance have been elaborated and await use.

The rations now provided are so constituted that they give protection against shortage of any constituent known to be essential, no matter how extreme the variation among individuals may be with respect to their requirement of that constituent. Since some of these essentials are very expensive, such a practice as this may be a weighty burden. It might prove to be sound policy to create by genetical methods, and this is the only way, strains in which the requirements of some of these more expensive accessory food factors and minerals are reduced to a minimum. In the fowl this objective has already been partly reached; there are strains which are highly resistant to Vitamin B and manganese deficiencies. There is every reason to expect that strains of livestock remarkable for their tolerance of sub-optimal levels of any of these factors and minerals could easily be created.

Veterinary Research.—The veterinarian is primarily concerned with the eradication of the environmental causes of defect and derangement. His task is to wrench the sickle from the grisly hand of unnecessary death and place it in the fist of the butcher. But we have reason to know that the conquest of a plague may herald the coming of a pestilence. A particular disease makes its appearance, grows in importance, wanes and gives place to another, and the discovery of a cure commonly coincides with the expected disappearance of that disease as an important cause of death. We have 'conquered' tuberculosis only to find that rheumatism is the real public enemy no. 1. By the time we have learnt how to conquer rheumatism it, in its turn, will be giving place to something else. So it is to be expected that the veterinarian will 'conquer' fowl paralysis, if sufficient time elapses before the cure is found. Having done so he will pass on, encouraged by his success and its associated rewards, to the conquest of its successor. His task is to gain the power of preventing all the serious diseases which affect the individual during the first half of its natural life span, for the diseases of senescence can be disregarded. It may be that the time has already arrived when more attention should be paid to the power of the individual to resist the attack of disease provoking organisms. It is established, for example, that by appropriate genetical methods strains of fowls not only highly resistant to specific diseases but also markedly resistant to disease in general can be established. It is not for me to argue that it would be sound policy to attack the problem of disease in this way: I must content myself by saying that it can be done.

Genetical Research.—All defective derangements are, however, not caused by agencies external to the individual, many are the direct expression of constitutional peculiarities. Many lethal and semi-lethal genes are known to exist in live-stock and to be directly responsible

for the death or the profound debility of the individual in whose hereditary constitution they are present. In the fowl, for example, five such genes are the causes of much death during incubation, whilst two others are largely responsible for the peak of mortality which occurs within the first fortnight after hatching. Others are known to be the cause of pre- and early post-natal mortality in the pig, sheep, and cattle. It is not improbable that the elimination of these lethals might prove to be a most effective means of raising the reproductive rate and of lowering the mortality rate in many stocks. But before they can be eliminated they must be discovered, and so another reason for extensive programmes of inbreeding is provided.

If the causes of death among a poultry population are examined it is found that disorders of reproduction, *e.g.*, ruptured oviduct, impacted oviduct, figure very highly. The prevalence of these conditions does not seem to be the direct result of any increase in productivity, and it is difficult to see how they can be prevented by modifications of husbandry. It would seem that selection for egg-number and egg-size is not also selection for an oviduct that can cope with such production. The eye of the breeder has been fixed on the ovary, and the oviduct, which apparently demands special attention, is overlooked. It has been shown by Greenwood that the size and degree of development of the oviduct are dependent upon harmonic control, and until further selection has produced an oviduct that will efficiently perform the task that is demanded of it, it may be that those now in use should be conditioned by appropriate harmonic theraphy. In any case it is the sex-physiologist's aid that is urgently demanded and not that of the pathologist.

The extension of the productive life of the individual is a matter of considerable importance. If, for example, it were possible to develop stocks of fowls which would maintain their first year's performance during a second and a third year, the whole structure of the industry would be altered. Greenwood's work seems to show that it is eminently possible by selection to achieve this objective, and all that is needed is a large-scale exploitation of the procedures already elaborated. In the meantime we must look to Cambridge and to Aberdeen for information concerning the possibility of extending the productive life by means of modifications in husbandry. In the rat it has been shown that the length of life can be extended by reducing the food intake, and in the fowl that neither the fastest nor the slowest growth-rates are compatible with maximum viability.

The attainment of early sexual maturity, the rhythm of the sexual cycle and through this the reproductive rate are qualities that can be manipulated genetically. But it takes time to 'fix' these qualities in a stock. With recent advances in sex and reproductive physiology

there has come into being the possibility of controlling them by other and simpler means. The syringe is replacing the seasons, for it is becoming possible by administering the appropriate hormones or their synthetic equivalents to exert a very complete control over the sexual and reproductive activities of our animals.

To me it seems that the time has now come when the live-stock industry must gain the power of controlling the secondary sex-ratio. It cannot much longer remain content to allow the numerical proportions of males and females among the newly-born in dairy herds of cattle and goats and in flocks of poultry to be decided by the operations of blind chance. Such power can be secured and, I think, should be secured. In the domesticated mammals this control if Walton's work at Cambridge is adequately encouraged, will emerge from researches relating to the separation of the two kinds of spermatozoa. If I may be permitted to be prophetic, and at the same time assume that the policies and programmes of live-stock improvement in the immediate future will be born of a lively intelligence, I predict that the time will come when all the sires that will be used will be congregated in a few centres, and that the beribbened swaggering stallion will be seen no more upon our roads. He will give place to a small glass phial enclosed within a registered letter. Then the progeny test will claim a reliability that at present it cannot hope to possess. In the case of poultry the problem of the control of the secondary sex-ratio will not so easily be solved, for here it is the female that elaborates the two kinds of gametes. In a poultry population, generally, it seems that there are two kinds of eggs: those being fertilized, destined to yield males, and those which inevitably will develop into females, are elaborated in equal numbers. But careful search may be expected to disclose individuals which habitually yield a preponderance of females. In other forms 'sex-ratio' genes have been identified and are known to disturb the mechanism responsible for the production of the two kinds of eggs. These genes can be incorporated into stocks by appropriate genetic procedures and by their aid a secondary sex-ratio of any desired dimension can be obtained. On the other hand, it may prove to be more desirable to transform the majority of male embryos into females during the earlier stages of incubation by means of injection of 'feminizing' hormones into the egg. Undoubtedly this can be done, but it remains to be shown that such a procedure can with advantage be transferred from the laboratory to the farm.

The Breeder.—I will end as I began, by reminding myself and you that the geneticist knows that inborn qualities find full expression only in an optimum environment. The most important feature in the environment of our live-stock is the breeder himself. The chief

prerequisite in all live-stock improvement is improvement of the men in charge, the practitioners of agriculture, the veterinarians, and especially the improvement of privileged people like myself who are given such plentiful opportunities for self-expression and for public service. The need for new knowledge is urgent, but knowledge remains sterile and wasted until it can be exploited in the true service of mankind. No research is of any considerable value until its benefits can be appreciated by the actual practitioners. Science has contributions to offer, but only to the educated and intelligent. The chief obstacle to the application of genetic principles in live-stock breeding commonly seems to be the inability on the part of the breeder to understand the jargon of the geneticist. Yet the man to whom heterozygosity is a mystery and linkage a myth speaks familiarly of the most intricate details of a tractor.

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